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Effect of Plate Surface Characteristics on Image Reproduction in Electrostatic Planographic Platemaking

Sung Jae Lee

EFFECT OF PLATE SURFACE CHARACTERISTICS ON IMAGE REPRODUCTION IN ELECTROSTATIC PLANOGRAPHIC PLATEMAKING

by

Sung Jae Lee

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in the School of Printing in the College of Graphic Arts and Photography of the Rochester Institute of Technology

May, 1983

Thesis adviser: Dr. Julius L. Silver

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CERTIFICATE OF APPROVAL

MASTER'S THESIS

This is to certify that the Master's Thesis of

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with a major in Printing Technology
has been approved by the Thesis Committee as
satisfactory for the thesis requirement for the
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An Abstract

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ABSTRACT

Four different types of surfaces of aluminum plates; 1) brush grained, 2) chemically grained, 3) brush grained and anodized, and 4) electrochemically grained and anodized substrates coated with polyvinyl oxazol, an organic photoconductor were studied. The experiments were divided into two parts. The first part concerned with the photoelectric characteristics of the various surfaces, and the second part was involved with image quality relative to photoelectric properties of different substrates.

The characteristics of each of the surfaces was briefly discussed. Photoelectric properties such as 1) photosensitivity, 2) spectral response, 3) surface acceptance potential, 4) dark decay, 5) light decay, 6) retentivity, and 7) residual potential of the various surfaces of the aluminum substrates were reported. Image quality of a variety of plates in terms of 1) resolution of halftones and line patterns, 2) edge sharpness, 3) solid fill-in, 4) image density, and 5) cleanliness of non-image area were analyzed.

The relationship of photoelectric properties vs. image quality of these surfaces was reported. Most of the experiments were repeated several times and the data were analyzed by statistical techniques, i.e., correlation, regression analysis, analysis of variance and multiple regression. The plates were not press tested.

Under experimental conditions, the electrochemically grained and anodized surface exhibited the best photoelectric properties as well as image quality. The (electro-) chemical graining of the plates provided better photoelectric properties when compared to mechanical graining. Anodizing the plate surface further improved photoelectric characteristics. Image quality was related to the photoelectric performance of surfaces of the plates.

Abstract approved:

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Date

CHAPTER I

INTRODUCTION

The success of xerography in the photocopying industry and in the offset duplicating industry provided the impetus for the investigation of potential applications of electrophotographic imaging techniques to commercial lithographic printing. Electrophotographic paper plates, such as the Electrofax[1] type or those obtained by transfer techniques, are suitable for short runs up to one thousand copies. A metal plate is required for longer runs over five thousand impressions. Several methods of xerographic image transfer techniques[2] were used for many years. A process of converting the photoconductive material to a water-receptive state has also been developed.[3] Many materials and equipment incorporating the reprographic camera type equipment and processor for copying and duplicating are now available.

These applications of the xerographic technique provided a rapid photographic method of preparing masters. The conventional steps used in processing negatives, and the photomechanical operations of preparing plates were eliminated. The speed, versatility, dependability, legibility and economy of processing these plates led to many uses in duplicating. Most inplant printing or duplicating shops already have an electrophotographic platemaking system.

These reprographic methods are working very well in duplicating and short run printing of line-work and type. However, they have not found wide commercial acceptance in quality printing houses. Any new platemaking processes, therefore, will have to measure up to commercial quality standards before it can become accepted in this field.

In the past few years electrophotographic metal plates for the newspaper field became more attractive. An automated electrophotographic projection camera platemaking system which eliminated the need for a negative, and the low power laser imaging techniques using an electrophotographic plate provided the impetus for investigating potential applications of electrophotographic technology in newspaper lithographic platemaking.

Statement of the Problem

Quality control is very important in printing reproduction. Printing plate quality has a decided effect on the quality of printing reproduction. Various grained plates for the electrophotographic platemaking processes are available. Because their surface structures and treatments are different, their effects on reproduction quality and performances in the platemaking process need to be investigated. The objective is to determine what type of grain and surface treatment provides the best substrate for the electrophotographic platemaking process. The best substrate refers to performance in platemaking as well as the reproduction qualities which include resolution, density and stability.

In this study the following types of grained aluminum plate will be used:

1. Brush grained surface
2. Chemically grained surface
3. Brush grained and anodized surface
4. Electrochemically grained and anodized surface

Hypotheses

The best surface of the aluminum substrate coated with a photoconductor for electrophotographic platemaking is the one which provides the following properties and capabilities:

1. Photoelectric properties:
    a. High photosensitivity
    b. Proper spectral response to exposure light source
    c. High acceptance of surface potential
    d. Slow dark decay
    e. Low residual potential, and
2. Image reproduction capabilities:
    a. High resolution
    b. High density
    c. Even solid fill-in
    d. Sharp edges of images
    e. Clean background

The purposes of these experiments were to find the relation of the grained surfaces and the photoelectric properties vs. image quality.

If there is a significant relationship of the photoelectric properties vs. image quality on the various aluminum surfaces, the electrochemically grained and anodized plates should be the best substrate for the electrophotographic platemaking. The electrochemical graining and anodizing is considered to be a clean and uniform graining process. Brush graining which tends to leave foreign particles such as dust, pumice, etc., on the unevenly grained surface should provide inferior photoelectric properties and image quality. The relationship of the photoelectric properties vs. image quality on the various surfaces of aluminum substrates may be measured to determine the best surface.

FOOTNOTES FOR CHAPTER I

[1]Young, C. J. and Greig, H. G., "R.C.A. Review" 15, 471, 1954.

[2]Rheinfrank, J. J., Kurz, P. F. and Myers, F. C., "Proceedings of Technical Association Graphic Arts," p. 133, 1957.

[3]Sugarman, M. L., "Proceedings of Technical Association Graphic Arts," p. 59-70, 1955.

[4]U.S. Pat. 3,037,861 Hoegl, H., to Kalle AG, 1962.
U.S. Pat. 3,290,146 Tomanek, M., to Azoplate Corp., 1966.
U.S. Pat. 3,615,385 Lind, E., to Kalle AG, 1971.
U.S. Pat. 3,653,886 Lind, E., Wiedemann, W. to Kalle AG, 1972.

CHAPTER II

REVIEW OF THE LITERATURE

The literature has indicated that there are differences in the spectral sensitivity of the selenium layer deposited on various metal bases. Grenichin and Cherkasov[5] experimented using amorphous selenium layers deposited on copper, iron, stainless steel, galvanized iron, polished dural and brass as a base material. The highest sensitivity was obtained with iron as the substrate base and the lowest with stainless steel, when the negative surface charge was applied. However, a report of Battelle Memorial Institute[6] showed that selenium deposited on chromium and brass indicated no appreciable difference in sensitivities for the two substrate materials with a positive charge.

Usually the effects are observed as differences in dark decay rates. Because light at the blue-green end of the visible spectrum does not penetrate amorphous selenium to the region of the substrate interface, it is not expected that conditions at the interface will affect the photosensitivity of the plates in this spectral region. However, for most films, red light does not penetrate to the substrate; therefore, interface conditions can change the red sensitivity. The photoconductivity excited by other more penetrating radiation, such as X-rays, also can be affected by the baseplate surface conditions. Various investigations have dealt with experiments on differing base-plate metals, different procedures for cleaning and surface treating of the metal base plate, and with the inclusion of very thin layers of insulating and semiconducting materials between the selenium and the base plate. The condition of the metal surface just prior to the deposition of the selenium layer, however, appears to be of greater importance than the kind of metal used. For high quality images a smooth, polished metal surface is essential; however, if the surface is not microscopically clean, defects will become apparent in the developed image. The "artefacts" observed by Limb and Metcalfe appear to be due to the substrate contaminants or surface defects.

The effects of the type and condition of the base metal surface were observed as differences in dark decay rates. Experiments dealing with cleaning and surface treatments of aluminum base plates have been reported by Schaffert, Williams and Walkup[7]. A considerable decrease in the potential-decay rate in the dark was obtained by cathodic treatment in trisodium phosphate solution, and a still further decrease in this dark-decay rate was found when the base plates were given an anodic treatment in either ammonium tartrate or sulfuric acid solution. Further evidence that dark decay is controlled primarily by interface conditions come from experiments with different interfacial materials.

Experiments on cleaning techniques for brass base plates were described in the same reports. Here a very marked decrease of potential-decay rate in the dark was obtained by including a polishing treatment with Glass Wax as one step in the cleaning procedure. A similar result was obtained when a solution of paraffin in benzene was substitued for the Glass Wax. Ramazanov[8] has observed that invisible irregularities on the surface of the substrate, such as grease spots, finger prints, etc., become visible after an evaporation of the selenium layer. He found chemical cleaning of the surface with 20% alkali for one hour, followed later by ion bombardment in the vacuum chamber, to be especially effective.

Chiang and Ing[9] made studies to determine the nature of surface interaction. They found that selenium films deposited on oxide-coated aluminum substrate in a relatively poor vacuum (10^{-5} Torr) could be peeled off easily, and the chemisorption of water does not impair adhesive strength. They attributed adhesion failure in coventional evaporator systems to surface absorption of vapor species. Oxide coatings are found on most metal surfaces. Therefore, the adhesion of photoconductor to a substrate is usually dependent upon the interaction between photoconductor and a surface oxide.

Amorphous selenium layers deposited on Nesa[10] glass substrates exhibited slow dark decay for positive charging, but very fast dark decay for negative charging.[11] When the layers were charged positively and exposed on the selenium side, the potential decayed to a relatively low value. Under the same conditions, when the plate was exposed through the glass side the potential decayed initially at about the same rate but to a higher residual potential. This is about what would be expected, because, for a positive charge on the selenium, and exposure through the glass side, the photocurrent would be electrons and the effect should be similar to charging the selenium with a negative charge and exposing on the selenium side. For negative charging, and exposure on the selenium surface, the residual potential is usually higher than in the case of positive charging. McNeil and Jolly[12] conducted experiments with amorphous selenium layers deposited on conductive substrates consisting of cadmium oxide coatings on glass. The oxide coatings, approximately 0.05 u thick, were obtained. Selenium layers in the range of 0.2 u to 16 u were obtained by vacuum evaporation with the substrate temperature maintained at 20^{o}C or below. This temperature was found to be necessary in order to insure adherent amorphous layers for the very thin coatings. They found that the dark decays were quite slow for both positive and negative charging, even for the very thin layers. Dark decay half-times of 30 to 60 minutes were reported. For positive charging, however, the rate of charge decay when exposed to white light was about twice the rate of decay for negative charging.

FOOTONTES FOR CHAPTER II

[5]Grenishin, S. G. and Cherkasov, I. A., "Zhur, Nauch. i Priklad. Fot. i Kinematog". . . 5,433, 1960, in Russian.

[6]Andrus, P. G., Clevland, B. B., et al, "4th Quarterly Progress Report," (May-Aug. 1951), pp. 4-16, 4-17, Battelle Memorial Institute.

[7]Schaffert, R. M. Williams, D. T. and Walkup, L. E. "Quarterly Progress Report, Nos. 5 and 6 (Sept-Dec. 1949) pp. 430-433, Battelle Memorial Institute.

[8]Ramazanov, K. A., Zhur. Nauch. i Priklad. Fot. i Kinematog., 6,440 (1961).

[9]Chiang, W-S, and Ing, S. W., Jr., Journal "Vacuum Sciente Techniques," 6,809, 1969.

[10]Nesa glass - a glass coated with a conductive layer of antimony and tin oxide combination, made by companies such as Corning Glass Works and PPG Industries, etc. Schaffert, R. M., "Electrophotography," The Focal Press, London and New York (1975).

[11]Schaffert, R. M., Williams, D. T. and Walkup, L. E. "Quarterly Progress Report No. 4, pp. 348-349 (Mar-June 1949) Battelle Memorial Institute, Signal Corps Contract No. W26-039 SC-36851 (ATI-178565).

[12]McNeil, J. F. and Jolly, D. J., Photo. Sci., 7,25 (1959).

CHAPTER III

DESIGN OF THE EXPERIMENT

The experiments were designed such that all the factors except one to be tested were controlled to obtain equivalent conditions. Most of the experiments were repeated to determine the consistancy of the results and also for the requirements of statistical analysis.

Many factors contribute to the changes of image reproduction, but to keep the study within manageable bounds, only the plate surface characteristics have been chosen. There are many electrophotographic platemaking methods using different materials, techniques and equipment. The experiments in this study were conducted using a laser platemaking system and aluminum plates coated with an organic photoconductor. The plates were then developed with a powder toner and the image was fixed by heat from an electric heater.

Experimental Procedures

Each of the following plate surface characteristics were used as a predictor for the changes in the image reproduction in electrostatic planographic platemaking:

1. Brush grained surface
2. Chemically grained surface
3. Brush grained and anodized surface
4. Electrochemically grained and anodized surface

The organization of the study is in five parts.

1. Measurement of the plate surface characteristics
2. Photoelectric characteristics and measurements
3. Electrophotographic platemaking
4. Analysis of electrophotographic images
5. Interaction between input and response variables

Part 1: Sample plates were collected from the electrophotographic offset plate manufacturer.[13] The plates were categorized by surface treatment techniques used for graining and anodizing. All plates were coated with polyvinyl oxazol,[14] an organic photoconductor under identical conditions. The coating weight of all plates were 5 g/m^2. This coating weight which is translated as 5 um in thickness is reported as most desirable thickness of organic photoconductor layer on aluminum substrate for printing platemaking purpose.

Part 2: Sample plates were collected from electrophotographic plate manufacturers. The following photoelectric characteristics of the plates were measured:

1. Photosensitivity[15]
2. Spectral response[16]
3. Acceptance of surface potential[17]
4. Retentivity (Dark decay)[18]
5. Residual potential[19]

Photosensitivity

The photosensitivity of electrophotographic plates is determined by the rate of decay of the electrical potential when the plate is illuminated. However, the effective speed of the plates is related to the particular imaging method and developing technique used, and for some materials, sensitivity depends upon the initial potential after charging. Also, differences in coating thickness, methods of preparation and formulation of an electrophotographic coating can produce appreciable changes in photosensitivity.

Spectral Response

An organic photoconductor such as polyvinyl carbazole, sensitized with a 1:1 molar equivalent of 2,3,7-trinitro-9-fluorenone is nearly panchromatic in the visible range of the spectrum. The zinc oxide-resin coating has a peak sensitivity in the near ultraviolet area with some sensitivity extending into the violet end of the visible spectrum. Dye-sensitization of the photoconductors extends the photosensitivity to include various ranges of the visible spectrum depending on the dyes used.

Acceptance Potential

The dark sensitivity of a photoconductive plate is a decreasing function of the electrical field applied across the plate. Thus, when a xerographic plate is sensitized, the amount of charge the plate will accept and hold is limited by the decreased resistance of the plate as the electrical field builds up to high values. This decreased resistance allows a greater amount of current to flow through the photoconductive coating of the plate, and as sensitizing is continued, a point is reached where charges leak away as fast as they are supplied. The plate potential at this point is called the "acceptance potential."

This is an important characteristic of electrophotographic plates since it is the primary factor in determining the amount of voltage contrast obtainable. Plates are usually sensitized to a potential somewhat below the acceptance potential in order to avoid subjecting the plate to undue electrical stress.

Retentivity

The length of time that an electrophotographic latent image is retained on an electrophotographic plate is determined by the rate of decay of the electrical potential in the dark. This is a function of the effective dark sensitivity of the plate. The type of coating material and the plate preparation method will determine its charge retentivity, which is usually measured as the time required for the plate potential to decay, in the dark, to one-half its original value.

Residual Potential

When a sensitized electrophotographic plate is exposed to light the electrical potential undergoes an internal rapid decay, followed by a relatively slow decay. The plate voltage at the point where the slow decay begins is called the residual potential. The potential may vary from near zero to as much as 30 or 40 percent of the acceptance potential. A low residual potential is a desirable characteristic of electrophotographic plates because of the greater voltage contrast obtainable.

Part 3: A variety of plates were made using an electrophotographic laser platemaking system which includes an automatic plate transport unit, corona discharge device, developing station and fusing

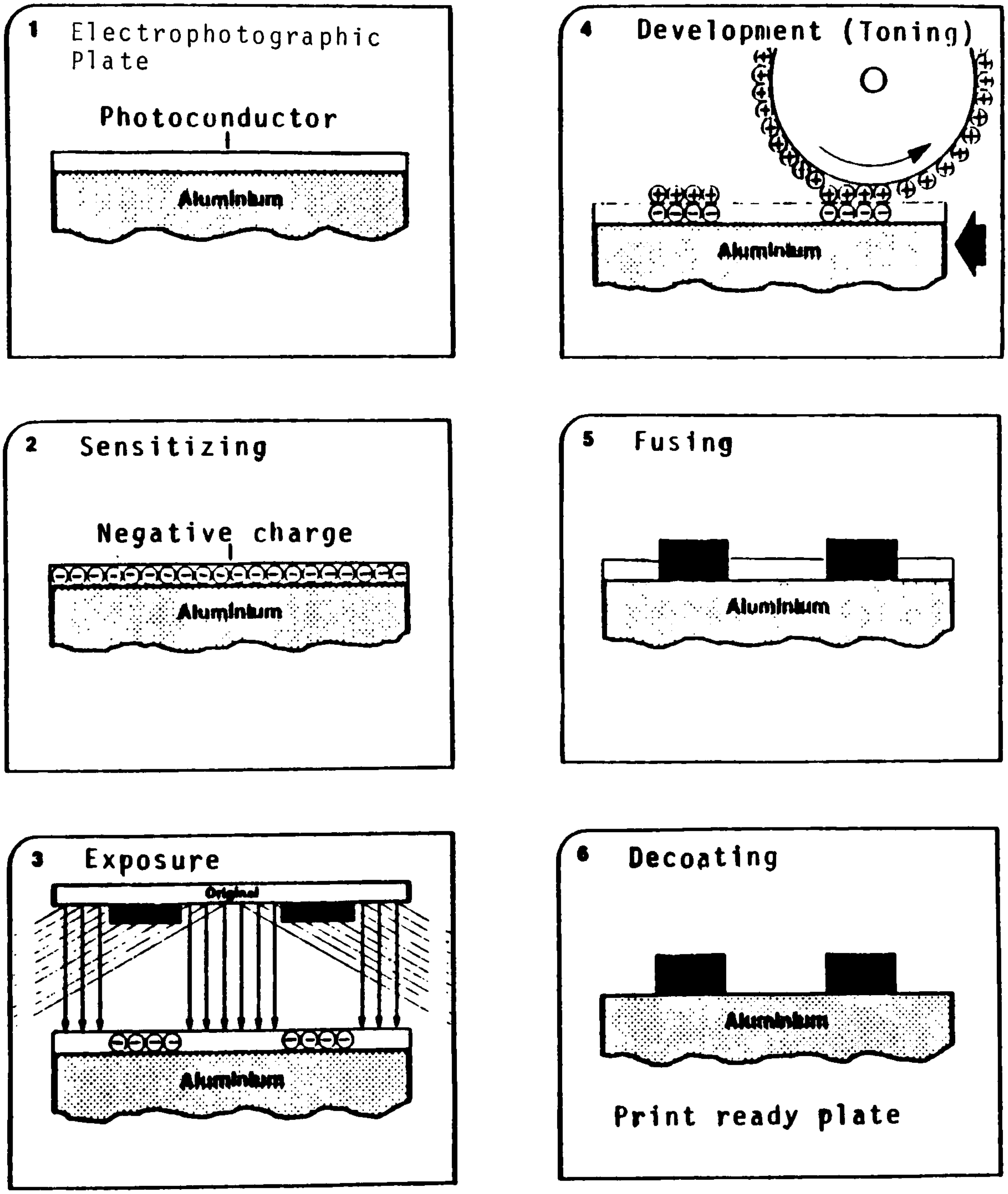

Figure 1. Principles of electrophotographic platemaking process

section. All variables in platemaking such as the voltage of corona discharge, exposure time, toner concentration and toning speed, developing electrode, fusing time and temperature were closely monitored. The humidity and temperature of the platemaking room was also controlled. An image test target was used for the imaging of the plates.

Figure 1 shows the principles of the electrophotographic platemaking process. Figure 2 is the cross section of LASERITE[R] 100E, an electrophotographic laser platemaking system used for the study. The system incorporates electronics and lasers. HeNe laser is used for the reading of original (pasteup) and an Argon Ion laser with a visible spectrum output (488 nm) is used for the writing of information (imagewise exposing) on the electrophotographic plate.

Part 4: the electrophotographic image of several plates was evaluated (After removing the oleophilic photoconductive coating in the non-image area) for the following:

1. Resolution
2. Density
3. Solid fill-in
4. Halftone vs. line and/or type
5. Non-image area

Part 5: An analysis of the interaction between input and response which are defined in part 1, 2, 3, and 4 of the study were undertaken. The following statistical methods; correlation, regression analysis, analysis of variance, and multiple regression were used to extract information from the data.

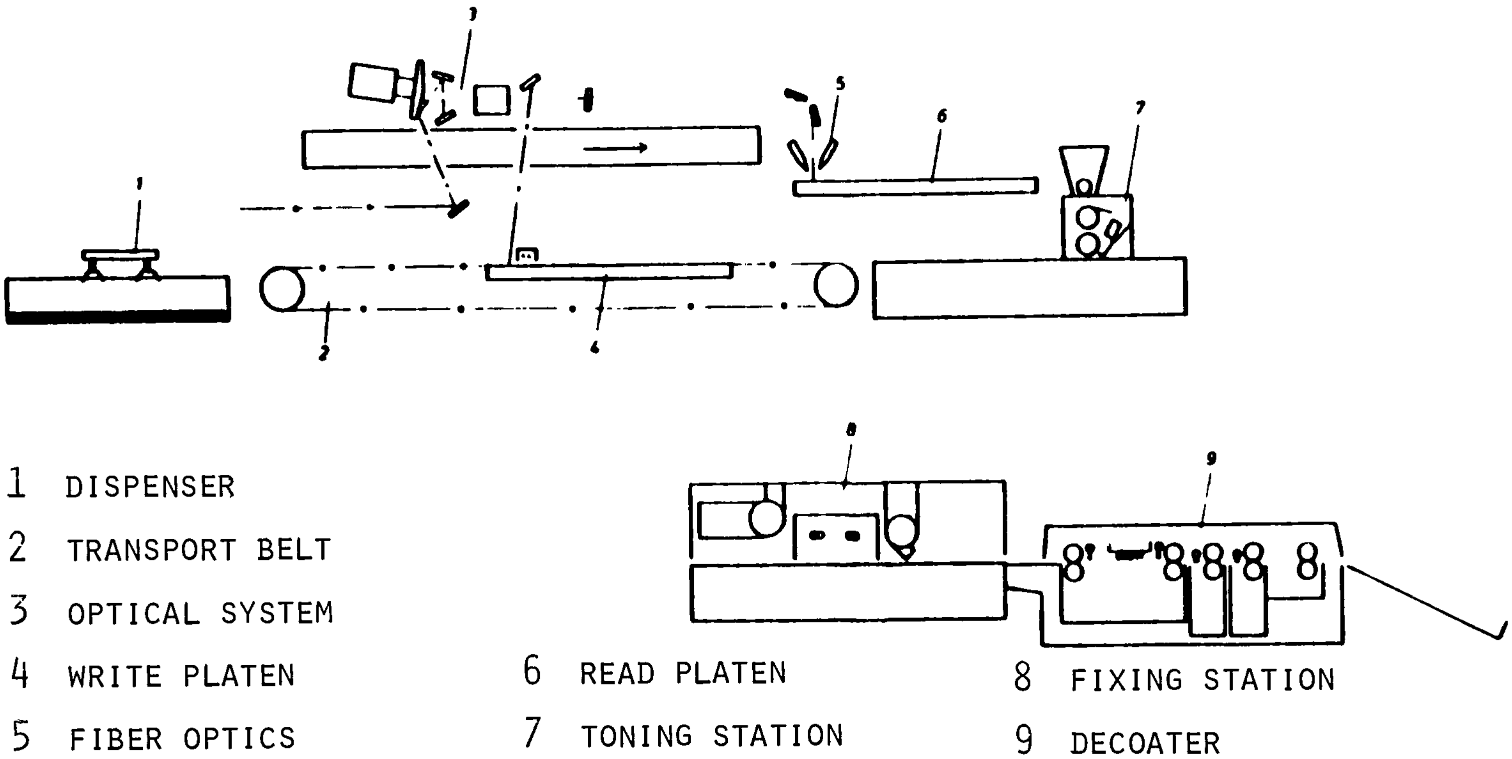

FIGURE 2. LASERITE[R] 100E, CROSS SECTION, EMPHASING THE ELECTROPHOTOGRAPHIC PARTS OF THE MACHINE

FOOTNOTES FOR CHAPTER III

[13]Azoplate, Div. of American Hoechst Corp., New Jersey.

[14]U.S. Pat. 3,615,385 Lind, E., to Kalle AG, 1971.
U.S. Pat. 3,653,886, Lind, E., Wiedemann to Kalle AG, 1972.

[15]Hayashi, Y., Hasegawa, M. and Ando, E., Preprints of paper summaries, 25th Annual Conf. SPSE, p. 116, 1972.

[16]Schaffert, R. M., IBM Journal, "Res. Development," 15, 75, 1971.

[17]Schaffert, R. M., IBM Journal, "Res. Development," 15, 84, 1971.

[18]Schaffert, R. M., Oughton, C. D., Journal "Opt Soc. Am.," 38, 991, 1948.

[19]U. S. Pat. 3,639,120, Selling C. to Xerox Corp. 1969.
U.S. Pat. 3,615,413, Fisher, C. B., Relyea, L. A. to Xerox Corp,. 1971
U.S. Pat. 3,427,157 Cerlon, P. J. to Xerox Corp., 1969.

CHAPTER IV

RESULTS OF ANALYSIS OF DATA

The following plates coated with polyvinyl oxazol which is an organic photoconductor, were obtained from the manufacturer:

1. Brush grained plate
2. Chemically grained plate
3. Brush grained and anodized plate
4. Electrochemically grained and anodized plate.

Table 1 summarizes the surface characteristics of variously treated aluminum plates and different weights of photoconductor layer. The data are provided by the plate manufacturer.

TABLE 1. PLATE SURFACE AND COATING WEIGHT

	Plate I	Plate II	Plate III	Plate IV
Grain Depth ($x\ 10^{-4}$ cm)				
Horizontal	1.5 - 2.0	0.7 - 1.1	1.7 - 2.5	2.0 - 3.0
Vertical	1.5 - 2.5	0.9 - 2.5	2.0 - 3.0	2.2 - 3.5
Grain Peaks (per cm)				
Horizontal	360 - 410	240 - 340	370 - 440	390 - 450
Vertical	370 - 420	250 - 570	360 - 500	410 - 490
Anodic Layer (g/m^2)	-	-	2.0	2.0
Organic Photoconductor Layer (g/m^2)	5	5	5	5

Plate I: Brush grained

Plate II: Chemically grained

Plate III: Brush grained and anodized

Plate IV: Electrochemically grained and anodized surface.

Photosensitivity of Plates

The photosensitivity of electrophotographic plates is determined by the rate of decay of the electrical potential when the plate is illuminated. However, the effective speed of the plate coating will be related to the particular imaging method and developing technique used, and for some materials sensitivity depends upon the initial potential after charging. Also, differences in coating thickness, methods of preparation and formulation of an electrophotographic coating can produce appreciable changes in photosensitivity.

The plates tested were coated using the same polyvinyl oxazol coating formula under identical coating conditions. Coating weights were also the same. Therefore, the basic photosensitivity of the plates were identical. However, the actual photosensitivity of the plates may differ from each other due to difference in their photoelectric properties of the plates. This is defined in the following sections of electrophotographic property measurement.

Spectral Response

The photosensitivity of polyvinyl oxazol is mostly in the blue-green area of spectrum, although some violet sensitivity is also present. Sensitivity is given as the reciprocal of exposure energy in ergs/cm^2. Figure 3 shows the sensitivity vs. wavelength plotted to show the spectral response of polyvinyl oxazol. It was measured using a Beckman Spectrophotometer UV5240. No measurable spectral sensitivity differences among the four different types of plates were observed.

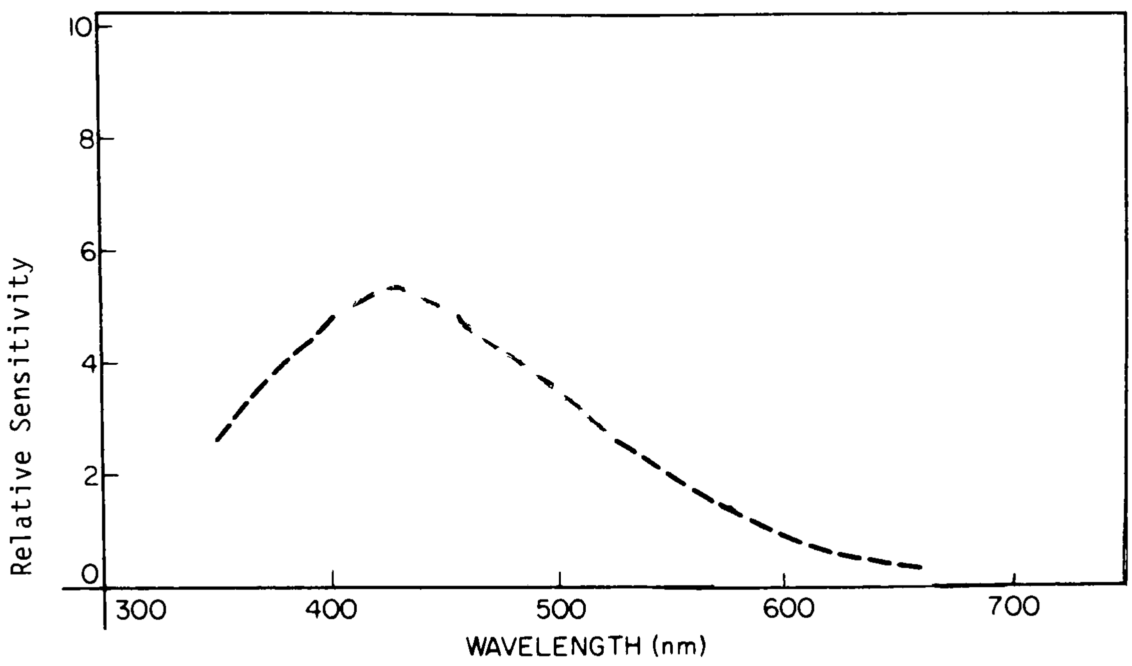

Figure 3. Spectral Sensitivity of Polyvinyl Oxazol.

Charging (Sensitizing) of Plates

The most effective and reliable sensitizing of electrophotographic plates is accomplished at present by spraying the plate surface with ions produced by corona discharge. When a potential of several thousand volts is maintained between the conductive base of a plate and the fine wires positioned near the photoconductive surface, corona emission from the wires ionizes air molecules which are drawn to the plate surface. Figure 4 illustrates the cross section of three practical arrangements for corona sensitizing. (1) consists of three parallel corona wires situated above the electrophotographic plate and below a grounded electrode strip. This is called the "3-wire corotron." (2) is similar to (1) except that a control grid of parallel wires is between the corona wires and the xerographic plate. This arrangement is called the "scrototron." The "Shielded corotron" is illustrated at (3). This unit consists of a single corona wire mounted in a grounded metal shield.

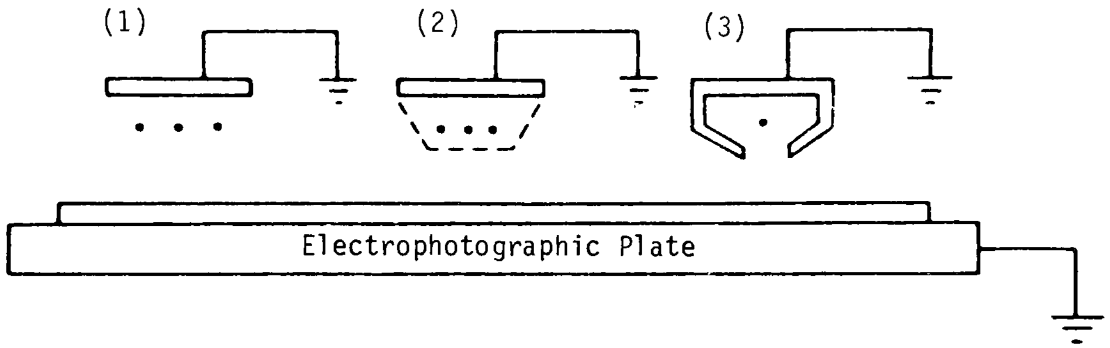

Figure 4. Corona Discharge Units.

A 3-wire corotron corona was used for the experiments, and the plates were sensitized by applying a negative charge. The procedure for sensitizing a plate with this unit to move the unit over the plate surface at a speed adjusted to provide the proper rate of charging. The charging rate is also a function of the potential applied to the corona wires. The corona voltage was maintained at about 7000 volts.

Corona sensitizing can be used to apply either positive or negative charges to a xerographic plate. The polarity of charging used depends on the particular characteristics of the photoconductive coating. Amorphous selenium performs better when sensitized with a positive polarity, whereas zinc oxide-resin coatings require a negative polarity. The plates used for the test were negatively charged.

Measurement of Surface Charge

Several electrometers, designed specifically for use in electrophotography, have been described in the literature.[20, 21, 22] Also various devices are available from instrument manufacturers for measuring surface charges on insulating materials.[23, 24] In the study of photoconductive insulators, however, the instrument must be capable of measuring accurately the rapid decay of surface charge during exposure to light. A sensing probe of transparent material such as Nesa-coated glass, is generally used for this purpose.[25] This permits continuous recording of the potential due to the surface charge. The electrometer must be sensitive and stable, and the electrometer-recorder system should have a rapid response, preferably in the millisecond range.

Dark decay of the surface charge, of course, can be measured with an opaque probe. Also, it is possible to measure light decay with such a probe by exposing and measuring in alternate steps. However, this procedure does not produce a true decay curve of the photoconductive layer, as pointed out by Ohyama, Kurita, and Takahashi.[25]

Electrometers of the rotating sector type design and manufactured by Monroe Electronics Laboratories of Middleport, New York were used for the measurements. These instruments provide essentially drift free performance and permit measurement of the electrostatic potential of a small area on a charged surface. A diagram showing the structure of this probe is shown in Figure 5. The sensing element is a

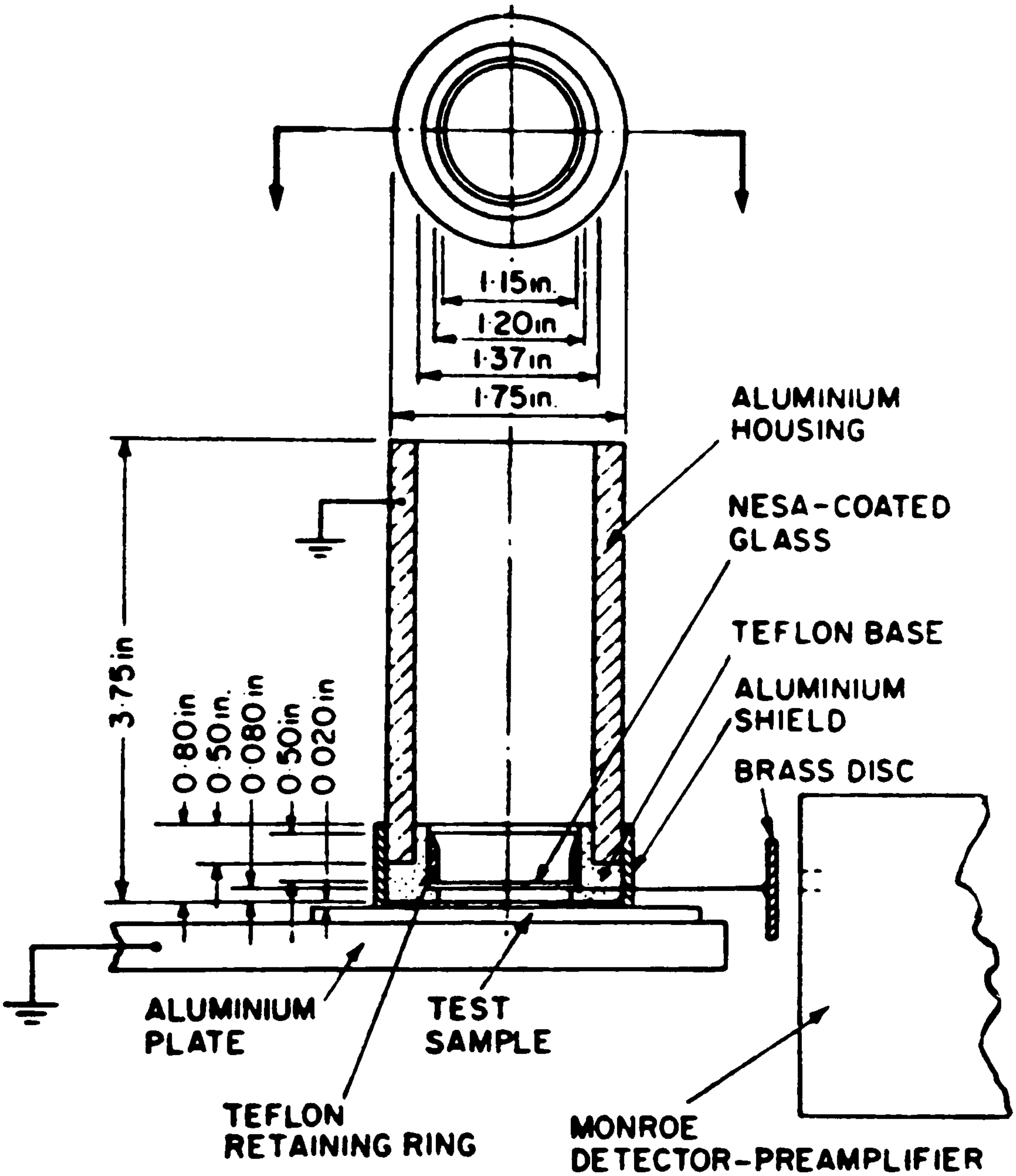

Figure 5. Diagram of an electrometer for measuring electrostatic surface voltage

Nesa glass plate, mounted at one end of a light-tight tube, and capacitively coupled to the detector-preamplifier of the Monroe apparatus.

In operation of the unit, light entering the tubular housing passes through the Nesa glass probe and is projected onto the photoconductive surface of the test sample. It is essential, of course, that the area of the test sample is as shown in Figure 6. The light used can come from a conventional platemaking light source. Neutral density filters can be inserted to alter the light intensity. For measurements requiring higher intensities of monochromatic illumination that are obtainable with a monochromator, narrow band interference filters can be used with a direct light source. In the arrangement shown in Figure 6, the tubular housing of the transparent probe is rigidly attached to the rotary head of the optical unit. This permits directing the light beam onto a photomultiplier for measurement of light intensity. The photomultiplier should be accurately calibrated in absolute energy units.

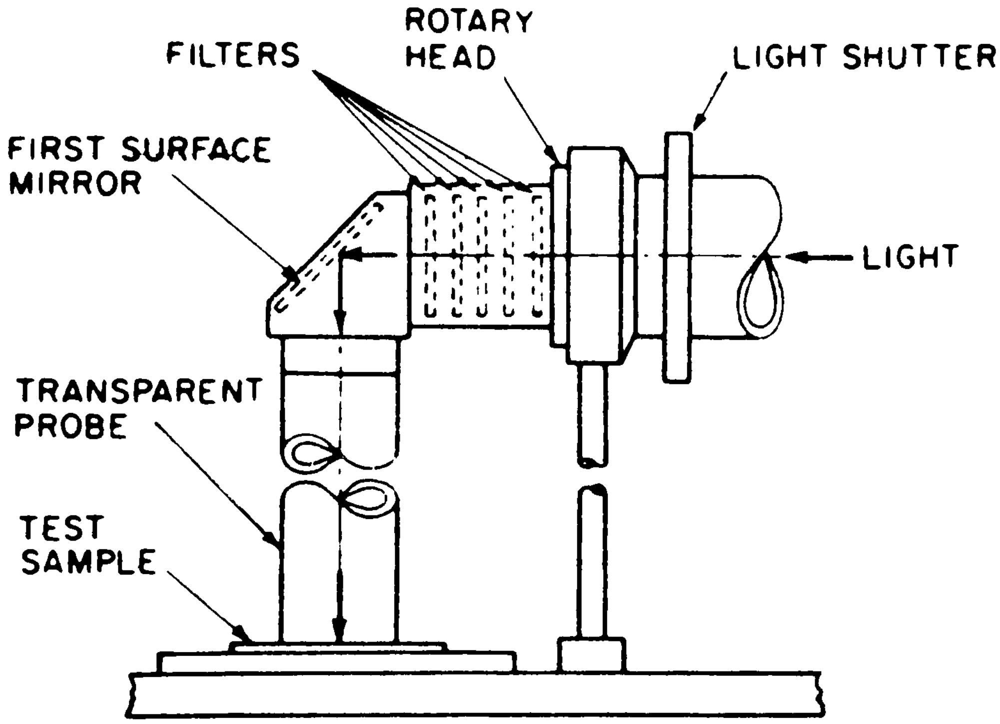

Figure 6. Optical System for Illuminating Test Sample Through Transparent Probe

The plates were negatively charged using a 3-wire corotron corona discharge unit (see Figure 4). Table 2 summarizes corona voltage vs. initial surface acceptance voltage.

TABLE 2. CORONA VOLTAGE VS. SURFACE VOLTAGE ACCEPTANCE

Corona Voltage (Volts)	Initial Surface Voltage (Volts)			
	Plate I	Plate II	Plate III	Plate IV
9000	602	607	605	613
8000	603	609	605	613
7000	512	527	523	536
6000	459	462	460	482
5000	340	350	348	360
4000	204	212	208	218
3000	136	139	137	141
2000	80	85	82	88
1000	63	67	66	70

Plate I: Brush grained

Plate II: Chemically grained

Plate III: Brushing grained and anodized

Plate IV: Electrochemically grained and anodized surface.

Overcharge effects were observed when a corona voltage was maintained over 8000 volts. Arcing during the charging and pinholes in the image area can be seen on an overcharged plate. A corona voltage maintained lower than 5000 volts was not sufficient to provide adequate surface voltage charge. A surface voltage of 400-500 volts which is required for electrophotographic aluminum printing platemaking, is obtained when a corona voltage is maintained at 6000-7000 volts.

The surface voltage acceptance is not proportionally increased when a corona voltage is maintained above 7500 volts. The acceptance potential of the surface coated with polyvinyl oxazol is approximately 600 volts of negative charge. The corona voltage was maintained at about 7000 volts during the test. The distance of corona to the photoconductive surface was maintained at 2.5 cm. The corona traveled for 25 inch length of charging surface in 4 seconds.

The electrochemically grained and anodized surface accepted the most surface voltage and brush grained plate accepted the least amount of surface voltage.

Measurement of Charge Decay

The length of time that the electrophotographic latent image is retained on an electrophotographic plate is determined by the rate of decay of the electrical potential in the dark. The plates charged with negative voltage are kept in the dark for measurement. Dark decay of the surface voltage is measured with an electrometer. Initial surface voltage was approximately 500 volts on the different surface. Table 3 summarizes the charge decay of different aluminum surfaces.

TABLE 3. DARK DECAY OF DIFFERENT SURFACES OF ALUMINUM SUBSTRATE COATED WITH AN ORGANIC PHOTOCONDUCTOR

Plates	Initial Voltage	Dark Decay (seconds)													
		5	10	15	20	30	40	50	60	70	80	90	100	110	120
Plate I	426	384	362	354	343	327	315	306	298	288	282	276	270	265	265
Plate II	441	396	379	365	353	342	333	326	323	320	316	312	308	305	305
Plate III	437	391	376	363	351	340	329	314	302	294	286	282	279	278	278
Plate IV	450	402	381	368	354	346	340	337	332	330	327	325	323	320	320

Plate I: Brush grained surface

Plate II: Chemically grained surface

Plate III: Brush grained and anodized surface

Plate IV: Electrochemically grained and anodized surface

Figure 7 shows dark decay curves of four different surfaces of aluminum plates. Dark decay in the first 5 seconds was very fast. Approximately 25% of the initial surface voltage on all the different plates was the decrease within 20 seconds. One-half of the surface voltage was reduced within 90 seconds. Thereafter the voltage remained very much constant up to a half hour.

It is noted that the brush grained plates have accepted less surface voltage than others. Fast dark decay was measured on the brush grained surface. Electrochemically grained and anodized surface exhibited slow dark decay. Also, the retentivity of these plates were lower than (electro-) chemically grained surfaces. It is believed that the (electro-) chemical graining provides cleaner surface with less foreign materials than the brush graining. Anodizing further improved acceptance potential and dark decay of the aluminum surface.

Light Decay and its Measurement

Electrophotographic printing plates are usually given a negative surface charge during the electrical sensitizing operation. In theory, this is done to take advantage of the better hole conduction through the organic photoconductor layer during illumination, which generally provides more efficient discharge than electron conduction. The optical absorption constant, in the region of greatest spectral sensitivity, is very high and therefore the light is almost totally absorbed in a very thin layer (approximately 5 u thick) at the photoconductive surface. Photons absorbed in this thin surface layer produce hole-electron pairs.

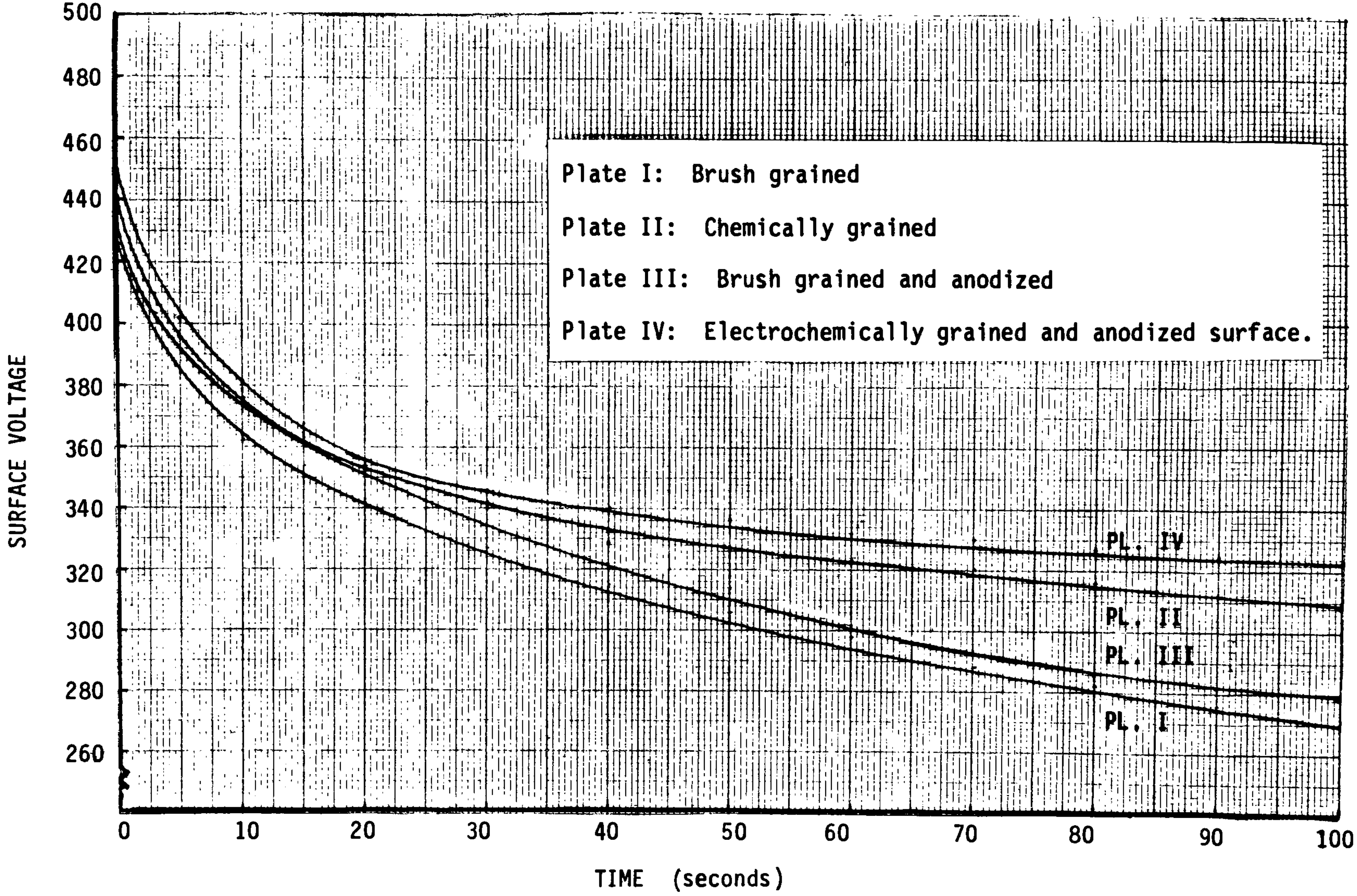

Figure 7. Dark Decay Curves of Different Surfaces of Aluminum Plate

With a negative surface charge, the holes will be driven toward the substrate while the electrons will be drawn toward the surface.

Table 4 is light decay data for the different surfaces of aluminum plates. The initial potential on a variety of surfaces is slightly different. This adjustment was necessary to keep constant corona voltage and to achieve appropriate surface voltage for practical applications. Constant intensity illumination of 30 u watts at 480 nm is used. The rate of decay decreases as the initial potential is reduced.

TABLE 4. LIGHT DECAY OF DIFFERENT SURFACES OF ALUMINUM PLATE

Plates	Initial Voltage	Light Decay (Seconds)									
		2	4	6	8	10	20	30	40	50	60
Plates I	426	242	125	80	70	69	67	65	64	63	63
Plates II	441	256	121	72	60	59	57	55	54	53	53
Plates III	437	249	123	77	67	64	60	59	58	57	57
Plates IV	450	258	126	69	58	55	53	52	51	50	50

Plate I: Brush grained

Plate II: Chemically grained

Plate III: Brush grained and anodized

Plate IV: Electrochemically grained and anodized surface.

When the sensitized surfaces are exposed to light the electrical potential undergoes an internal rapid decay, followed by a relatively slow decay. The surface voltage at the point where the slow decay begins is called the residual potential. The residual potential of the surfaces tested appears at 6 to 10 seconds. However, it depends on the intensity of illumination and initial voltage acceptance. A low residual potential is a desirable characteristic of electrophotographic plates because of greater voltage contrast obtainable.

Ten seconds of illumination appears to be the proper length of exposure for plates. The lowest residual potential of 50 volts is measured on electrochemically grained and anodized surface. Brush grained surfaces exhibited 63 volts of the residual potential. Figure 8 shows the effects of light intensity on the rate of decay of the surface potential.

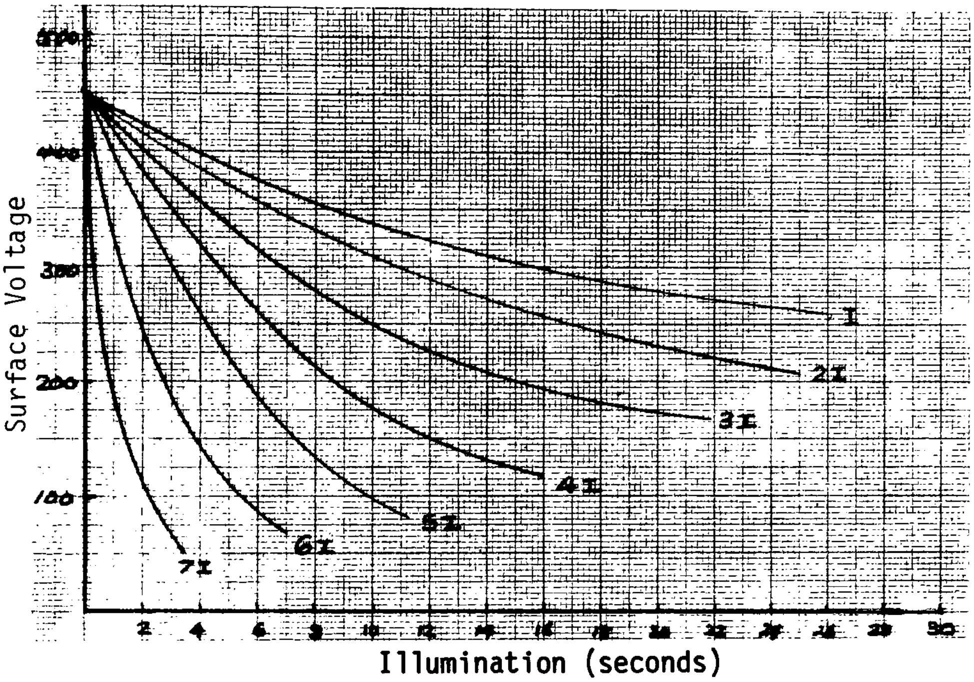

Figure 8. Effects of Light Intensity on the Rate of Decay of the Surface Potential

Electrochemically grained and anodized surfaces were used for the test. I = 5, 2I = ID, 3I = 20, 4I = 40, 5I = 80, 6I = 100, and 7I = 320 μ watts illumination. I is illumination intensity of argon ion visible laser (488 nm spectrum).

Imaging on Plates

The plates charged with negative voltage were then exposed to 488 nm spectrum of Argon Ion laser. An exposure of 25 μj/cm^2 was given to produce best image on the surfaces tested. The image was developed using a liquid toner charged with positive voltage. Figure 9 shows the technique used for image development. The electrophoretic precipitation from liquid dispersion media is capable of fine-grain development of electrophotographic images.

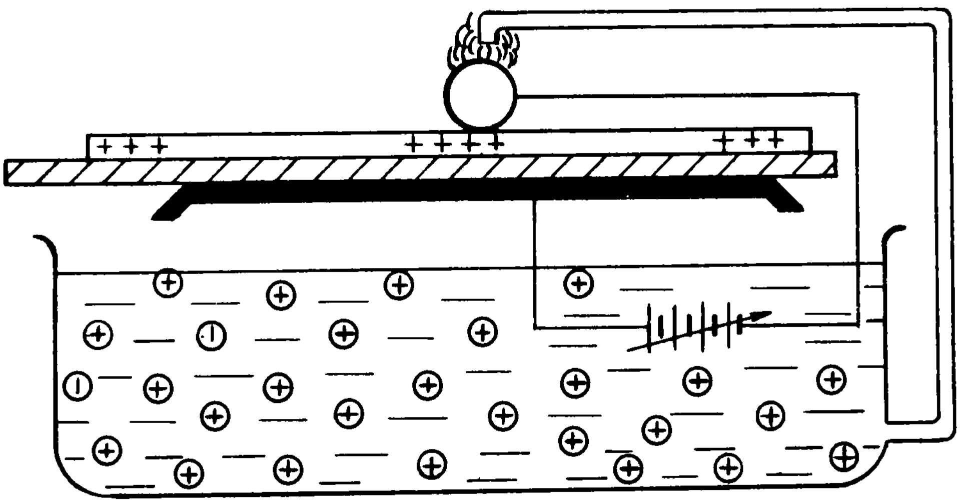

Figure 9. Liquid Electrophoretic Development.

An infra red heater was used for image fixing. The developed image was heat treated for 10 seconds at 300°C. Following the image fixing, the photoconductor layer in the non-image area was then removed using an alkaline solution in a processor. The plates were then press ready and used for image quality analysis.

Image Analysis

Ten of each different substrates were imaged and used for analysis. A microscope was used for resolution testing and cleanness of non-image area evaluation. Density of image was measured using a reflection densitometer. Solid fill-in was visually measured and compared to each other plates.

As can be seen in the Figure 10 a line pattern of 3 and 4, and 2 and 4 mil black and white line/space areas of the image test target was examined for line resolution capability. A halftone scale from 5 to 90% of 100 line screen areas was used for the halftone reproduction test. The number of toner particles deposited in one square inch of non-image area was measured using a microscope for the cleanness of background examination.

Table 5 summarizes the image quality analysis. The electrochemically grained and anodized substrate exhibited the best image quality. The plate is capable of producing 2 mil line as well as space with sharp edges, 5 to 90% of 100 line/inch halftone dots, evenly dense solid fill-in and relatively clean background. The chemically grained plate exhibited similar quality image, except slightly low solid fill-in.

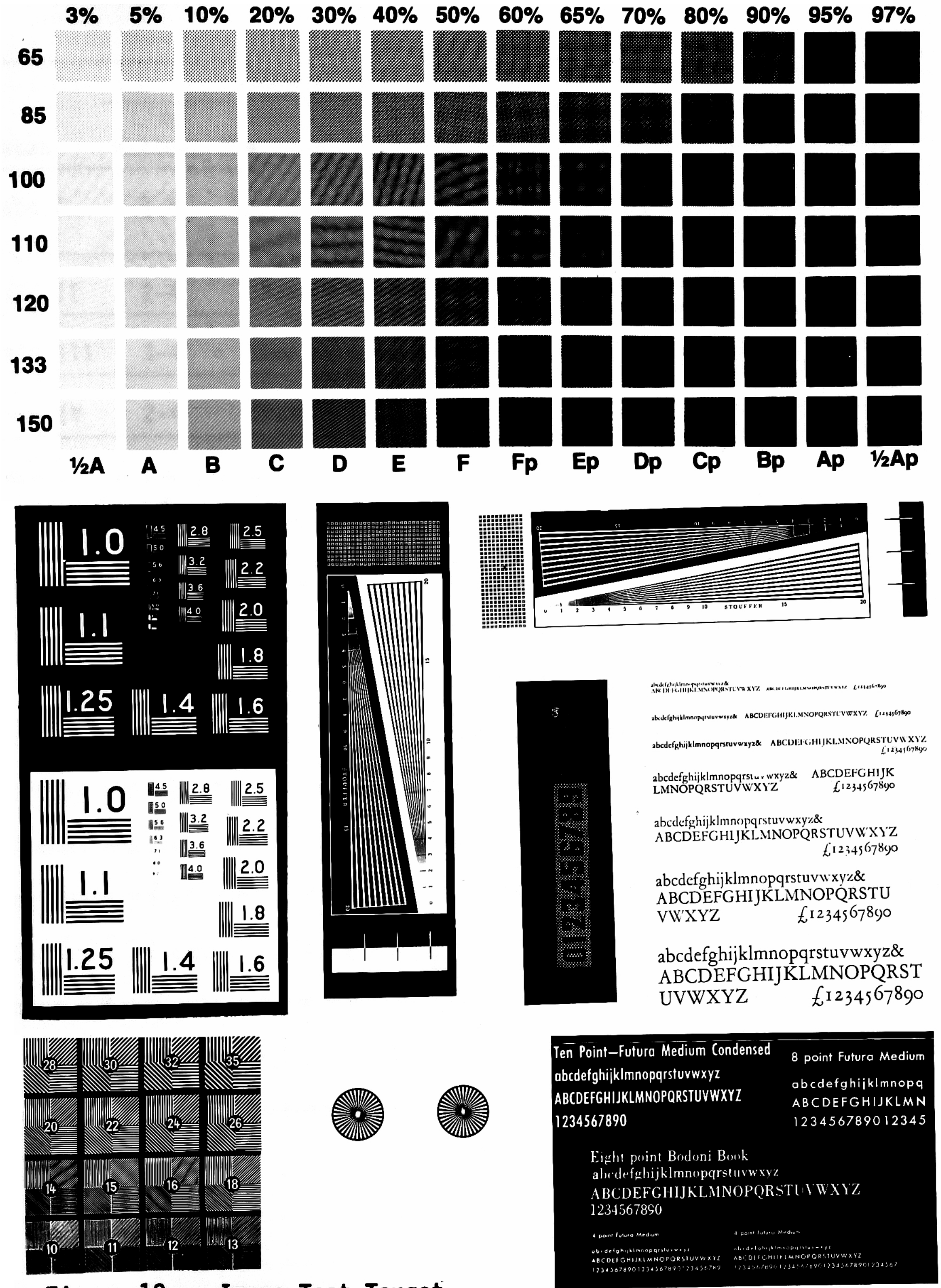

Figure 10. Image Test Target

TABLE 5. IMAGE ANALYSIS DATA

Plates	Resolution: Line Pattern	Resolution: Edge Sharpness	Resolution: Halftone (100 Line/Inch)	Reflection Density	Solid Fill-In	Non-Image Area
Plate I	3-4	Unsharp	10-80%	1.92	Uneven Dense Edge	5
Plate II	2-4	Sharp	5-90%	2.01	Good	3
Plate III	3-4	Sharp	10-80%	1.98	Good	4
Plate IV	2-4	Sharp	5-90%	2.03	Excellent	3

Plate I: Brush grained

Plate II: Chemically grained

Plate III: Brush grained and anodized

Plate IV: Electrochemically grained and anodized surface.

Low quality image can be seen on the brush grained substrate. Line edges of 3 and 4 mil line and the space area was not sharp. Halftone dots smaller than 10% of 100 line screen were not reproduced and over 80% dots of the shadow area was plugging. Uneven solid fill-in with dense edges were also observed. The background was not as clean as with Plate II and IV. The brush grained and subsequently anodized plate showed slightly better images than that of brush grained substrate, but not as good as chemically grained (Plate II), and electrochemically grained and anodized plate (Plate IV).

FOOTONTES FOR CHAPTER IV

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CHAPTER V

CONCLUSIONS AND RECOMMENDATIONS

The experiments were designed to study and compare the effects of surface treatment of aluminum substrate for electrophotographic printing platemaking. The effects are analyzed in terms of photoelectric properties of different surfaces coated with an organic photoconductor, and the image quality of these plates made under identical conditions. Test surfaces included; 1) brush grained, 2) chemically grained, 3) brush grained and anodized, and 4) electrochemically grained and anodized surface. They were prepared using the same organic photoconductor (polyvinyl oxazol) formula and coating procedures.

The photoelectric properties of the surfaces were examined under controlled environment. Argon Ion laser with a spectral output at 488 nm was used for imaging of the plates. Test image on the press ready plates was evaluated for image quality analysis. The plates were not press tested.

The plates used for the study exhibited the following characteristics: Electrochemically grained and anodized plate exhibited deep graining and large surface area (large number of grain peaks). Chemically grained surface showed shallow graining and small number of grain peaks. The brush grained plate can be located in between these two plates. The number of grain peaks and surface areas of the brush grained plate appeared slightly increased when it was subsequently anodized.

Photoelectric Characteristics

The photoelectric properties of the plates tested were satisfactory for lithographic platemaking process. The electrochemically grained and anodized surface was capable of accepting a high surface potential and exhibited slow dark decay and fast light decay. Great voltage contrast in image vs. non-image area was obtained on the electrochemically grained and anodized plate.

The brush grained plate accepted a low surface potential, and showed fast dark decay and high residual voltage. The plate which was deep grained, cleaned and anodized exhibited the best photoelectric properties. It is believed that the photoelectric properties of the brush grained surface is low due to foreign materials which remain on the surface due to the nature of mechanical graining.

Image Quality

The electrochemically grained and anodized plate was capable of producing good quality image, in terms of resolution, density, solid fill-in, and clean background. Such quality image was expected on the surface which possessed the best photoelectric properties.

The brush grained plate showed a low quality image hence it exhibited low photoelectric properties. The image quality on the chemically grained plate was similar to that of electrochemically grained and anodized plates. Reproduction quality appeared to be proportional to the photoelectric properties of surface substrate.

Recommendation for Further Study

In the future work, in-depth analysis of the surface of brush grained aluminum plate may be required. A method to quantify the foreign materials on the grained surface should be found.

In the study, image quality was analyzed by examining the plates. A test of the plates on the press is recommended for further analysis of image quality. However, a controlled materials and conditions are essential for a meaningful press test.

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